Color balance of RGB images

A guide of Bernhard Hubl

1. INTRODUCTION

A good color balance of CCD images can be reached 'manually' through inspection of the RGB image by the eyes. This method is often not perfect, especially when working with deep images and images with low object height.

My method is based on the 'Color Imaging' chapter of 'The Handbook of Astronomical Image Processing', written by Richard Berry und James Burnell.

In the first step one has to measure the RGB ratio of the used telescope – filter – camera system. Provided that the average object height during RGB exposure is known, the extinction (=wave length dependant weakening of a light ray when passing earth's atmosphere) can be corrected and the color balance can be reached considering the measured RGB ratio.

We want to reach a color balanced RGB image without doing manual adjustments!

2. MEASUREMENT OF THE RGB RATIO WITH A G2 STAR

This measurement should be done with several stars in several nights to get a result with a high accuracy.

2.1. Selection of suitable stars

The stars should fulfil the following criteria:

- Spectral type G1, G2 or G3 (our sun is a G2 star)
- Stars near culmination (the influence of the extinction is lower)
- Suited brightness: Do not use too bright stars (maximum 50% of saturation level)

The following stars are proposed by Richard Berry and James Burnell:

Table 1 Bright sun-like stars (m_v < 7 mag)

Name	Catalog	RA_{2000}	DE_{2000}	Sp. Type	m_V	Const.
	BS 9107	00 04 53.6	+34 39 56	G2V	6.11	And
	HD 1461	00 18 41.7	-08 03 04	G3	6.47	Cet
9 Cet	HD 1835	00 22 51.7	-12 12 34	G2.5	6.39	Cet
18 Cet	BS 0203	00 45 28.6	-12 52 51	G2V	6.16	Cet
	HD 4915	00 51 10.7	-05 02 23	G0V	6.98	Cet
	HD 8262	01 22 17.7	+18 40 57	G2V	6.93	Psc
	BS 483	01 41 47.1	+42 36 49	G1.5V	4.97	And
	HD 20619	03 19 01.8	-02 50 36	G1.5	7.05	Eri
ζ^1 Ret	BS 1006	03 17 46.2	-62 34 32	G2.5V	5.51	Ret
ζ^2 Ret	BS 1010	03 18 12.9	-62 30 23	01.5V	5.23	Ret
λ Aur	BS 1729	05 19 08.4	+40 05 57	G2IV/V	4.71	Aur
	HD 44594	06 20 06.1	-48 44 28	G2	6.61	Car
	HD 45184	06 24 43.8	-28 46 48	G2	6.37	Col
	HD 53705	07 03 57.2	-43 36 29	G1.5	5.56	Pup
	HD 76151	08 54 17.9	-05 26 04	G2	6.01	Hya
20 LMi	BS 3951	10 01 00.6	+31 55 25	G3	5.37	LMi
35 Leo	HD 89010	1016 32.2	+23 30 31	G1.5V	5.97	Leo
47 UMa	BS 4277	10 59 27.9	+40 25 49	G0V	5.04	UMa
	HD 96700	11 07 54.3	-30 10 22	G I	6.52	Hya
	HD 102365	11 46 31.0	-40 30 01	G3	4.89	Cen
	BS 5384	14 23 15.2	+01 14 30	G1V	6.27	Vir
	BS 5596	14 50 20.2	+82 30 43	F9V	5.64	UMi
ψ Ser	BS 5853	15 44 01.6	+02 30 54	G2.5	5.87	Ser
39 Ser	BS 5911	15 53 12.0	+13 11 48	G1	6.08	Ser
	HD 144585	16 07 03.2	+14 04 16	G2	6.31	Ser
λ Ser	BS 5868	15 46 26.5	+07 21 11	G0V	4.42	Ser
18 Sco	BS 6060	16 15 37.1	-08 22 11	G2Va	5.50	Sco
	HD 152792	16 53 32.2	+42 49 30	G0V	6.83	Her
	BS 6538	17 32 00.9	+34 16 15	G5V	6.56	Her
	HD 168874	18 20 49.1	+27 31 50	G2IV	7.01	Her
	HD 177082	19 02 38.0	+14 34 02	G2V	6.90	Aql
16 Cyg A	BS 7503	19 41 48.8	+50 31 31	G1.5V	5.99	Cyg
16 Cyg B	BS 7504	19 41 51.8	+50 31 03	G2.5V	6.24	Cyg

	HD 187237	19 48 00.7	+27 52 10	G2III	6.90	Vul
	BS 7569	19 52 03.4	+11 37 44	G0V	6.16	Aql
	BS 7683	20 05 09.7	+38 28 42	G5IV	6.19	Cyg
	BS 7914	20 40 45.1	+19 56 07	G5V	6.44	Del
	BS 8964	23 37 58.5	+46 11 59	G5	6.60	And

Table 2 Faint sun-like stars (m_v > 8 mag)

Name	RA_{2000}	DE_{2000}	m_V	Sp. Type	Const.
SA 140-84	00 03 38	-28 41 46	11.961	G?	Sci
SA 92-276	00 56 27	+00 41 52	12.036	G5	Cet
SA 93-101	01 53 18	+00 22 25	9.734	G5	Cet
vB64	04 26 40	+16 44 49	8.10	G2	Tau
SA 92-249	05 57 07	+00 01 11	11.733	G5	Ori
SA 98-682	06 52 16	-00 19 42	13.749	G?	Mon
Rubin 149B	07 24 18	-00 33 07	12.642	G?	CMi
SA 101-321	09 55 40	-00 18 52	12.85	G7	Sex
SA 101-329	09 56 19	-00 26 28	11.99	G7	Sex
SA 102-1081	10 57 04	-00 13 12	9.903	G5	Leo
SA 102-370	10 56 34	-01 10 40	11.229	G2	Leo
SA 103-487	11 55 11	-00 23 38	11.874	G5	Vir
SA 103-204	11 57 27	-00 56 53	11.189	G7	Vir
SA 104-483	12 44 17	-00 27 33	12.08	G5	Vir
SA 105-56	13 38 42	-01 14 14	9.975	G5	Vir
SA 107-684	15 37 18	-00 09 50	8.433	G3	Ser
SA 107-998	15 38 16	+00 15 23	10.436	G3	Ser
SA 196-1801	17 11 08	-60 06 29	12.755	G?	Ara
SA 110-361	18 42 45	+00 08 04	12.425	G5	Aql
SA 112-1333	20 43 12	+00 26 15	9.977	G2	Aqr
SA 133-276	21 42 27	+00 26 20	9.074	G5	Aqr
SA 114-654	22 41 26	+01 10 11	11.83	GO	Aqr
HD 219018	23 12 39	+02 41 10	7.708	G1	Psc
SA 115-2688	23 42 31	+00 52 11	12.487	G?	Psc
SA 115-271	23 45 42	+00 45 14	9.695	G2	Psc

The Excel tool „G2_Calculator.xls“ delivers a comfortable possibility to find quickly a suitable G2 star for every observing location and for every time. The first worksheet (with the name “Search G2 Stars”) contains all stars, which are suggested by Richard Berry and James Burnell, and a number of additional stars, which are suggested by the author.

Search G2 stars

Latitude [°]: 47,9635 North
Longitude [°]: 14,12806 East
Local Date: 06.01.2010
Local Time: 15:30:30
Time zone offset: -1
UT Date: 06.01.2010
UT Time: 14:30:30

Get time from PC | Get time offset from PC | Select stars | Select all stars | Sort by altitude | Sort by RA

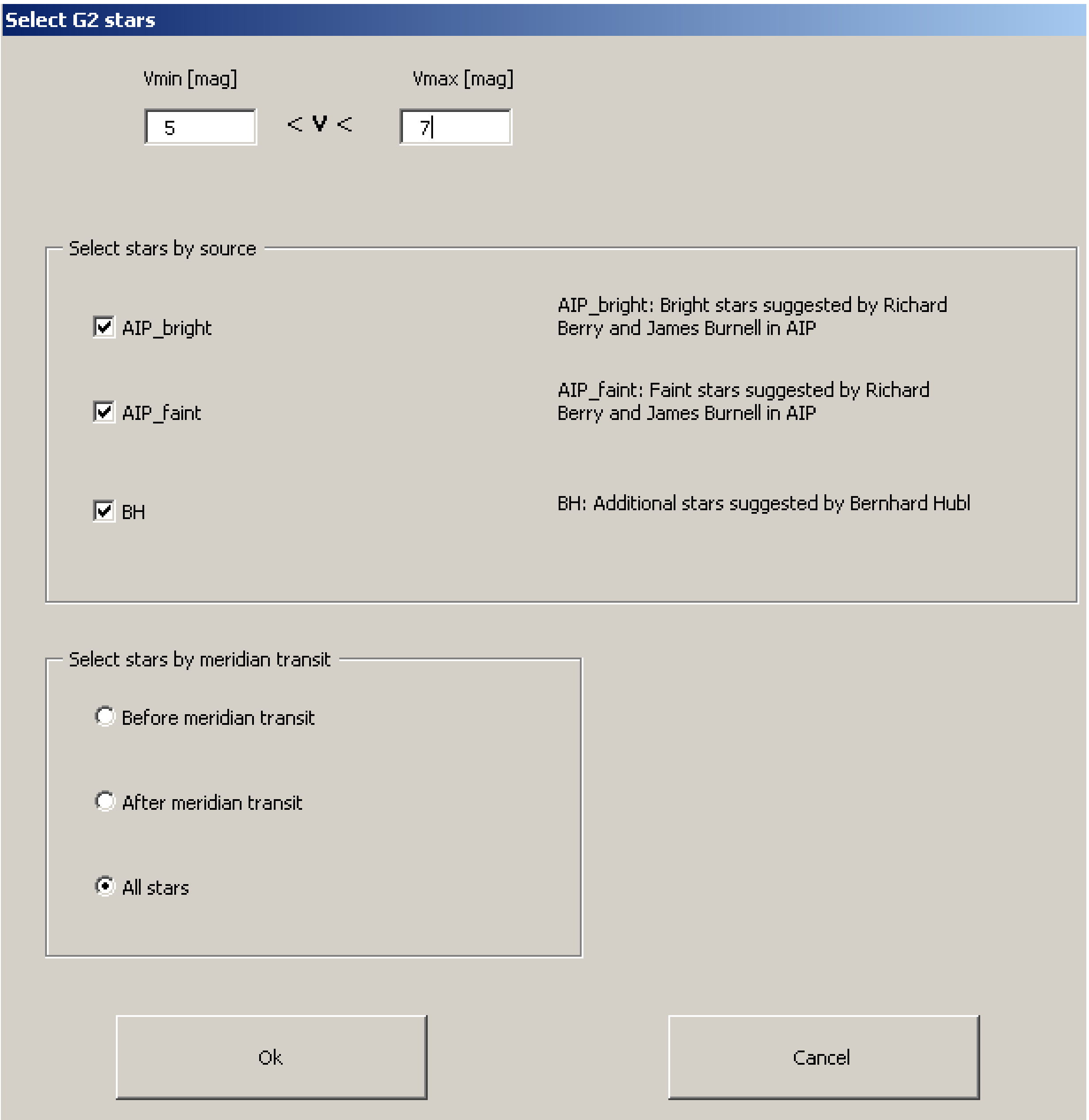
							[mag]	[mag]		[hh mm ss]	[deg
Name	BS	HD	HIP	Other	source	Sp. Type	B-V	V	Const	RA_2000	DE_
		224828	81		BH	G5	0,64	8,6	Psc	00 00 58,4	-0
				SA 140-84	AIP_faint	G?		12,0	Scl	00 03 37,9	-2
	9107	225239	394		AIP_bright	G2	0,63	6,1	And	00 04 53,8	+3
		483	759		BH	G2	0,64	7,1	Peg	00 09 19,4	+1
		1196	1290		BH	G5	0,66	9,4	Scl	00 16 10,3	-2
		1320	1382		BH	G5	0,65	8,0	Phe	00 17 16,5	-4
	72	1461	1499		AIP_bright	G0	0,67	6,5	Cet	00 18 41,9	-0
9 Cet	88	1835	1803		AIP_bright	G3	0,66	6,4	Cet	00 22 51,8	-1

The following inputs (indicated by the blue color) are necessary to select the best star:

- Latitude
- Longitude
- Date
- Time
- Time zone offset

Date and time refer to the local time. The local time is usually the same time, which is used by the PC. So, it makes sense to use the button “Get time from PC” to set the fields “Local Date” and “Local Time” automatically. The time zone offset is the difference between Universal Time (UT) and local time. The button “Get time offset from PC” sets the field “Time zone offset” to the offset, which is used by the PC.

The next step is to reduce the list of stars by pushing the button “Select stars”. The following window appears.



The first two inputs (Vmin and Vmax) restrict the list of stars by their V brightness. The best choice for the “Select stars by source” frame is to activate all three checkmarks. The “Select stars by meridian transit” is interesting for all astrophotographers, which work with a German equatorial mount. One can restrict the list of stars to stars, which are in the eastern sky (Before meridian transit) or to stars, which are in the western sky (After meridian transit). The Ok button activates the selection.

The button „Sort by altitude“ helps you to find the star with the highest altitude. This star can be found in the first row of the list.

The button „Select all stars“ deactivates all restrictions and you can see the complete list of stars.

The button “Sort by RA” gives you the possibility to sort the list of stars by their right ascension.

2.2. Exposure of the G2 star(s)

If you have found a suitable star, then you have to expose the star with the same exposure time through each of the three color filters. All images should stay below 50% of the saturation level. To get a good accuracy, you should expose at least 30 images through each filter.

The image reduction should be made as usual (dark and flat correction).

2.3. Determination of the RGB ratio

One can measure the brightness of the star through each filter with a standard CCD software (e.g. AIP4WIN, AstroArt,…). You get 3 signal levels.

The white light of the standard star is weakened when passing earth’s atmosphere: blue is strong weakened, green is less weakened and red shows the smallest weakening. This is the reason, why the star shows more red color in comparison to an exposure in zenith.

This reddening through earth’s atmosphere can be corrected with the Excel tool “G2_Calculator”. We open the second worksheet with the name “Measure G2 Star“.

Measurement of one G2 star

Input the average height of the star, along with the three signal values derived from ~30 com

height =	60 °	Height of the G2 star
Ar =	0,982	Transmittance in R
Ag =	0,972	Transmittance in G
Ab =	0,959	Transmittance in B

	Measured ADU signal	Extinction-corrected signal	Exposure ratio at zenith
R	23768	24205	1,000
G	56935	58598	0,413
B	45755	47712	0,507

Save in database

You have to input four values (indicated by the blue color):

- Height of the G2 star
- 3 measured ADU signal levels

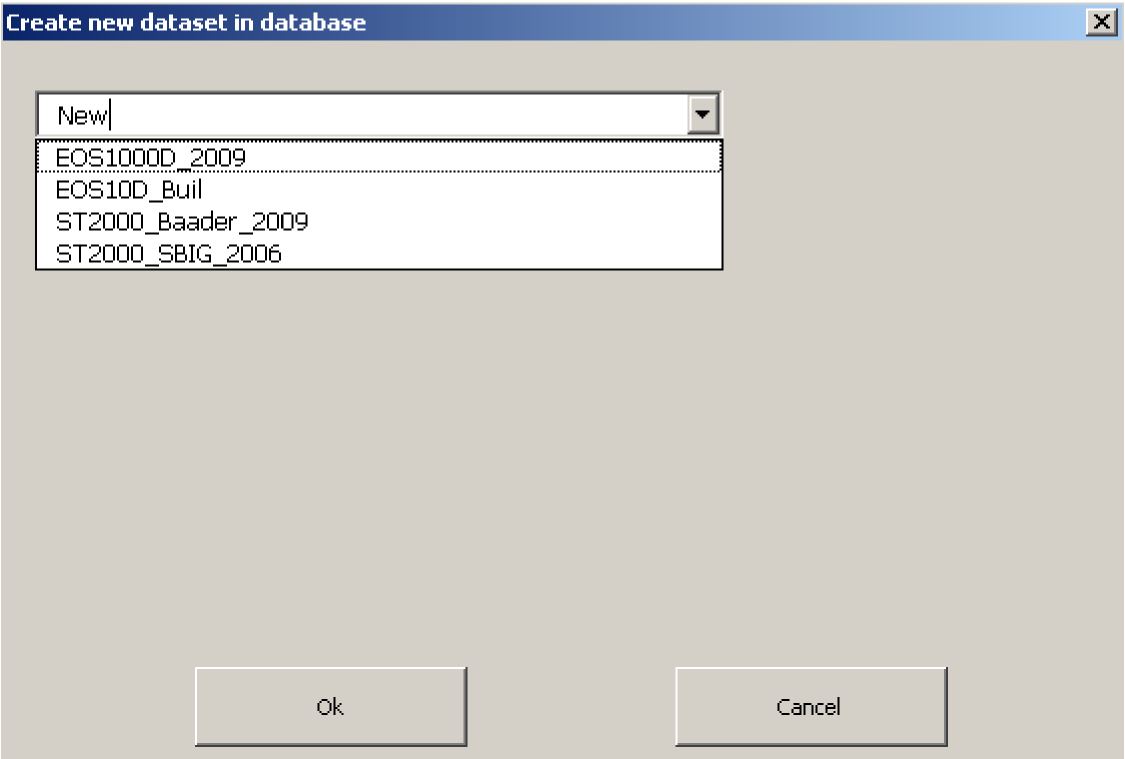
The result is the optimum RGB exposure ratio at zenith.
My ST2000XM with SBIG filters delivered the following ratio:

R:G:B = 1.0 : 0.44 : 0.56

So, there are some differences to the values of the manufacturer: SBIG gives the following ratio:

R:G:B = 1.0 : 0.5 : 0.5

Finally, you can save these color weights in a database by pushing the button “Save in database”. The following window appears:



You should input a unique, non existing name for the new dataset. The dataset is created, when you push the Ok-button.

The third worksheet of the G2_Calculator with the name „Database of Color Weights” contains a list of color weights.

Database of color weights

Name for identification	R	G	B	Date	Camera	Filter	Optics	Observer
EOS1000D_2009	2,03	1	1,52	12.09.2009	EOS1000D	none	Rubinar300	Bernhard Hubl
EOS10D_Buil	1,96	1	1,23	01.01.2004	EOS10D	none	-	Christian Buil
ST2000_Baader_2009	1	0,94	0,98	06.08.2009	ST2000XM	Baader	NP101	Bernhard Hubl
ST2000_SBIG_2006	1	0,44	0,56	07.07.2006	ST2000XM	SBIG	NP101	Bernhard Hubl

3. COLOR BALANCE OF OBJECT EXPOSURES

3.1. Making the RGB exposures

The RGB images should be made at approximate same height. An exposure near culmination is preferable.

3.2. Exposure time of single exposures

In theory it would be possible to choose the optimum RGB ratio, calculated with G2_Calculator. For example: If I expose an object with my ST2000XM at a height of 35°, then the fourth worksheet (Color Balance of Image) delivers the optimum RGB ratio for this height.

Color balance of an image

Extinction coefficients		***Ratio at zenith***	
kr =	0,128	R_Zenith	**1**
kg =	0,202	G_Zenith	**0,44**
kb =	0,294	B_Zenith	**0,56**

Import from database

Transmittance	
Ar =	0,916
Ag =	0,871
Ab =	0,818

Input the average height of the object, the number of R exposures, and the exposure durations

height =	**35**	°	Average height of object during exposure
n_R =	**5**		Number of exposures in R
t_R =	**600**	s	Single exposure time of R
t_G =	**300**	s	Single exposure time of G
t_B =	**300**	s	Single exposure time of B

	Optimum ratio at object height	Optimum number of exposures	Filter multiplication factor
R	1,000	5,0	1,000
G	0,463	4,6	0,926
B	0,627	6,3	1,255

The first step is to import the color weights at zenith from the database by clicking on the button “Import from database”. It is also possible to input the color weights manually in the blue cells. If you input the desired height in the blue cell “height” (in our case: 35°), then you get for the optimum ratio at object height:

R:G:B = 1,0 : 0,46 : 0,63

I could choose an exposure time of 10 min for red, 4.6 min for green and 6.3 min for blue. The color balance would be reached automatically.

In practice this method is not preferable. One would have to adjust the single exposure times for each image because of different object heights. You would have to shoot a lot of darks!

This is the reason, why I use the same single exposure time independent from the object height. My standard exposure times for my ST2000XM with SBIG filters at my 4" refractor are:

R 10 min / G 5 min / B 5 min.

3.3. Number of single exposures

If the object height is big, then I shoot the same number of single exposures with each filter. If the object height is small (below 30°) then the num ber of blue exposures should be increased. At very low object height also the number of green exposures should be slightly increased. The optimum number of single exposures can be calculated with the fourth worksheet of the G2_Calculator:

First of all, you have to enter the RGB ratio, which was determined with the G2 star method, into the fields R_zenith, G_zenith and B_zenith. Next, you enter the average object height during RGB exposure. The last step is to enter the planned number of red exposures (n_R) and the planned single exposure times (t_R, t_G, t_B). Then you get the optimum number of single exposures in column 'Optimum number of exposures'.

3.4. Color balance of the object image

After you have captured the raw images and you have done the image reduction and registration, the combination of the single exposures can be done. If the number of red, green and blue exposures is the same, then you can combine the images through addition or average. If you have a different number of single exposures through the three color filters, then you should use the average method for the combination.

Before the combined red, green and blue images can be combined to a RGB image, you have to multiply the green and blue images with a factor. These factors can be found in the column "Filter multiplication factor".

E.g: I made several RGB exposures of the galaxy NGC253 at a very low average height (13°). You can have a look on the image data in the following table:

Table 3 Exposure data of NGC253 image

	Exposure data	Optimum RGB ratio	Optimum number of exposures	Filter multiplication factor
R	4 x 480s	1,00	4,0	1,00
G	5 x 240s	0,56	4,5	1,11
B	7 x 240s	0,95	7,6	1,90

Without any manual corrections on the color balance I got the following image (full resolution on my website www.astrophoton.com):